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Pest categorisation of *Dendrolimus spectabilis*

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Abstract

The EFSA Panel on Plant Health performed a pest categorisation of *Dendrolimus spectabilis* (Lepidoptera: Lasiocampidae), a moth, also known as the Japanese pine caterpillar, for the European Union (EU). *D. spectabilis* is native to China, Japan and Korea. Its larvae primarily feed on the needles of *Pinus densiflora* and *P. thunbergii* and can also feed on *P. strobus*, *P. rigida*, *P. taeda* and *P. tabuliformis*. The pest can have one or two generations per year; winter is mostly spent as fifth instar larvae in the soil. Adults emerge in July and August and females lay egg masses of 200–300 eggs on coniferous host needles. Natural enemies are described as significant factors of population density changes in Japan and the Republic of Korea. The pest can be detected visually, and there are morphological keys as well as molecular markers allowing identification. *D. spectabilis* could enter the EU, either as eggs, larvae or pupae in the foliage of plants for planting or cut branches, as larvae on wood with bark or as overwintering larvae in the litter of potted plants. However, Annex VI of Regulation 2019/2072 prohibits the introduction of *D. spectabilis* hosts from countries and areas where the pest occurs. *D. spectabilis* occurs in climatic zones that are found in the EU, and the fact that it attacks the North American *P. strobus, P. taeda* and *P. rigida* in its Asian native area suggests a potential to shift to local conifer species in the EU territory. There is uncertainty regarding the magnitude of economic and environmental impact of *D. spectabilis* on conifer species commonly occurring in the EU. Notwithstanding this uncertainty, *D. spectabilis* satisfies all the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest.

Keywords: Japanese pine caterpillar, Lasiocampidae, *Pinus*, pest risk, plant health, plant pest, quarantine

Requestor: European Commission

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Table of contents

1. Introduction

1.1. Background and Terms of Reference as provided by the requestor

1.1.1. Background

The new Plant Health Regulation (EU) 2016/2031, on the protective measures against pests of plants, is applying from 14 December 2019. Conditions are laid down in this legislation in order for pests to qualify for listing as Union quarantine pests, protected zone quarantine pests or Union regulated non-quarantine pests. The lists of the EU regulated pests together with the associated import or internal movement requirements of commodities are included in Commission Implementing Regulation (EU) 2019/2072. Additionally, as stipulated in the Commission Implementing Regulation 2018/2019, certain commodities are provisionally prohibited to enter in the EU (high risk plants, HRP). EFSA is performing the risk assessment of the dossiers submitted by exporting to the EU countries of the HRP commodities, as stipulated in Commission Implementing Regulation 2018/2018. Furthermore, EFSA has evaluated a number of requests from exporting to the EU countries for derogations from specific EU import requirements.

In line with the principles of the new plant health law, the European Commission with the Member States are discussing monthly the reports of the interceptions and the outbreaks of pests notified by the Member States. Notifications of an imminent danger from pests that may fulfil the conditions for inclusion in the list of the Union quarantine pest are included. Furthermore, EFSA has been performing horizon scanning of media and literature.

As a follow-up of the above-mentioned activities (reporting of interceptions and outbreaks, HRP, derogation requests and horizon scanning), a number of pests of concern have been identified. EFSA is requested to provide scientific opinions for these pests, in view of their potential inclusion by the risk manager in the lists of Commission Implementing Regulation (EU) 2019/2072 and the inclusion of specific import requirements for relevant host commodities, when deemed necessary by the risk manager.

1.1.2. Terms of Reference

EFSA is requested, pursuant to Article 29(1) of Regulation (EC) No 178/2002, to provide scientific opinions in the field of plant health.

EFSA is requested to deliver 53 pest categorisations for the pests listed in Annex 1A, 1B, 1D and 1 E (for more details see mandate M-2021-00027 on the Open.EFSA portal). Additionally, EFSA is requested to perform pest categorisations for the pests so far not regulated in the EU, identified as pests potentially associated with a commodity in the commodity risk assessments of the HRP dossiers (Annex 1C; for more details see mandate M-2021-00027 on the Open.EFSA portal). Such pest categorisations are needed in the case where there are not available risk assessments for the EU.

When the pests of Annex 1A are qualifying as potential Union quarantine pests, EFSA should proceed to phase 2 risk assessment. The opinions should address entry pathways, spread, establishment, impact and include a risk reduction options analysis.

Additionally, EFSA is requested to develop further the quantitative methodology currently followed for risk assessment, in order to have the possibility to deliver an express risk assessment methodology. Such methodological development should take into account the EFSA Plant Health Panel Guidance on quantitative pest risk assessment and the experience obtained during its implementation for the Union candidate priority pests and for the likelihood of pest freedom at entry for the commodity risk assessment of High Risk Plants.

1.2. Interpretation of the Terms of Reference

Dendrolimus spectabilis is one of a number of pests listed in Annex 1B to the Terms of Reference (ToRs) to be subject to pest categorisation to determine whether it fulfils the criteria of a potential Union quarantine pest for the area of the EU excluding Ceuta, Melilla and the outermost regions of Member States referred to in Article 355(1) of the Treaty on the Functioning of the European Union (TFEU), other than Madeira and the Azores, and so inform European Commission decision making as to its appropriateness for potential inclusion in the lists of pests of Commission Implementing Regulation (EU) 2019/ 2072. If a pest fulfils the criteria to be potentially listed as a Union quarantine pest, risk reduction options will be identified.

1.3. Additional information

D. spectabilis was identified as a pest of *Pinus thunbergii* in a commodity risk assessment of black pine (*Pinus thunbergii* Parl.) bonsai from Japan (EFSA PLH Panel, 2019), and in a commodity risk assessment of bonsai plants from China consisting of *Pinus parviflora* grafted on *Pinus thunbergii* (EFSA PLH Panel, 2022).

2. Data and Methodologies

2.1. Data

2.1.1. Literature search

A literature search on *D. spectabilis* was conducted at the beginning of the categorisation in the ISI Web of Science bibliographic database, using the scientific name of the pest as search term. Papers relevant for the pest categorisation were reviewed, and further references and information were obtained from experts, as well as from citations within the references and grey literature.

2.1.2. Database search

Pest information, on host(s) and distribution, was retrieved from the European and Mediterranean Plant Protection Organization (EPPO) Global Database (EPPO, online), the CABI databases and scientific literature databases as referred above in Section 2.1.1.

Data about the import of commodity types that could potentially provide a pathway for the pest to enter the EU and about the area of hosts grown in the EU were obtained from EUROSTAT (Statistical Office of the European Communities).

The Europhyt and TRACES databases were consulted for pest-specific notifications on interceptions and outbreaks. Europhyt is a web-based network run by the Directorate General for Health and Food Safety (DG SANTÉ) of the European Commission as a subproject of PHYSAN (Phyto-Sanitary Controls) specifically concerned with plant health information. TRACES is the European Commission's multilingual online platform for sanitary and phytosanitary certification required for the importation of animals, animal products, food and feed of non-animal origin and plants into the EU, and the intra-EU trade and EU exports of animals and certain animal products. Up until May 2020, the Europhyt database managed notifications of interceptions of plants or plant products that do not comply with EU legislation, as well as notifications of plant pests detected in the territory of the Member States and the phytosanitary measures taken to eradicate or avoid their spread. The recording of interceptions switched from Europhyt to TRACES in May 2020.

GenBank was searched to determine whether it contained any nucleotide sequences for *D. spectabilis* which could be used as reference material for molecular diagnosis. GenBank® (www.ncbi.nlm.nih.gov/genbank/) is a comprehensive publicly available database that as of August 2019 (release version 227) contained over 6.25 trillion base pairs from over 1.6 billion nucleotide sequences for 450,000 formally described species (Sayers et al., 2020).

2.2. Methodologies

The Panel performed the pest categorisation for *D. spectabilis*, following guiding principles and steps presented in the EFSA guidance on quantitative pest risk assessment (EFSA PLH Panel et al., 2018a), the EFSA guidance on the use of the weight of evidence approach in scientific assessments (EFSA Scientific Committee et al., 2017) and the International Standards for Phytosanitary Measures No. 11 (FAO, 2013).

The criteria to be considered when categorising a pest as a potential Union quarantine pest (QP) is given in Regulation (EU) 2016/2031 Article 3 and Annex I, Section 1 of the Regulation. Table 1 presents the Regulation (EU) 2016/2031 pest categorisation criteria on which the Panel bases its conclusions. In judging whether a criterion is met the Panel uses its best professional judgement (EFSA Scientific Committee et al., 2017) by integrating a range of evidence from a variety of sources (as presented above in Section 2.1) to reach an informed conclusion as to whether or not a criterion is satisfied.

The Panel's conclusions are formulated respecting its remit and particularly with regard to the principle of separation between risk assessment and risk management (EFSA founding regulation (EU)

No 178/2002); therefore, instead of determining whether the pest is likely to have an unacceptable impact, deemed to be a risk management decision, the Panel will present a summary of the observed impacts in the areas where the pest occurs, and make a judgement about potential likely impacts in the EU. While the Panel may quote impacts reported from areas where the pest occurs in monetary terms, the Panel will seek to express potential EU impacts in terms of yield and quality losses and not in monetary terms, in agreement with the EFSA guidance on quantitative pest risk assessment (EFSA PLH Panel et al., 2018a). Article 3 (d) of Regulation (EU) 2016/2031 refers to unacceptable social impact as a criterion for quarantine pest status. Assessing social impact is outside the remit of the Panel.

Table 1: Pest categorisation criteria under evaluation, as derived from Regulation (EU) 2016/2031 on protective measures against pests of plants (the number of the relevant sections of the pest categorisation is shown in brackets in the first column)

Criterion of pest categorisation	Criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest (article 3)
Identity of the pest (Section 3.1)	Is the identity of the pest clearly defined, or has it been shown to produce consistent symptoms and to be transmissible?
Absence/ presence of the pest in the EU territory (Section 3.2)	Is the pest present in the EU territory? If present, is the pest in a limited part of the EU or is it scarce, irregular, isolated or present infrequently? If so, the pest is considered to be not widely distributed.
Pest potential for entry, establishment and spread in the EU territory (Section 3.4)	Is the pest able to enter into, become established in, and spread within, the EU territory? If yes, briefly list the pathways for entry and spread.
Potential for consequences in the EU territory (Section 3.5)	Would the pests' introduction have an economic or environmental impact on the EU territory?
Available measures (Section 3.6)	Are there measures available to prevent pest entry, establishment, spread or impacts?
Conclusion of pest categorisation (Section 4)	A statement as to whether (1) all criteria assessed by EFSA above for consideration as a potential quarantine pest were met and (2) if not, which one(s) were not met.

3. Pest categorisation

3.1. Identity and biology of the pest

3.1.1. Identity and taxonomy

Is the identity of the pest clearly defined, or has it been shown to produce consistent symptoms and/or to be transmissible?

Yes. The identity of the species is established and *Dendrolimus spectabilis* (Butler) is the accepted scientific name and authority.

D. spectabilis (Butler) is an insect within the order Lepidoptera and family Lasiocampidae. Synonyms are *Odonestis spectabilis* Butler and *Oeona segregatus* Butler. It is commonly known as the Japanese pine caterpillar.

The EPPO code[1] (Griessinger and Roy, 2015; EPPO, 2019) for this species is: DENDSC (EPPO, online).

[1] An EPPO code, formerly known as a Bayer code, is a unique identifier linked to the name of a plant or plant pest important in agriculture and plant protection. Codes are based on genus and species names. However, if a scientific name is changed the EPPO code remains the same. This provides a harmonised system to facilitate the management of plant and pest names in computerised databases, as well as data exchange between IT systems (Griessinger and Roy, 2015; EPPO, 2019).

3.1.2. Biology of the pest

The biology of *D. spectabilis* has been described by Choi et al. (2011, 2019) in the Republic of Korea, and a good general synthesis is also provided by Bell et al. (2015). The species was univoltine (one generation per year) in the Republic of Korea but is presently bivoltine (two generations per year) in the central part of the country due to climate change (Choi et al., 2011). *D. spectabilis* is also bivoltine in Japan (Honshu) (Kokubo, 1965). In univoltine populations, most larvae hibernate in the soil under the snow, mostly as fifth instar larvae, go back to the trees in the spring of the following year and start spinning their cocoons on pine branches in mid-July. The adults emerge in late July and August and the females lay egg masses of 200–300 eggs on pine needles in August. The larvae hatch from August to September. In bivoltine populations, the first generation of adults emerges in July, lays eggs that hatch, and the larvae develop rapidly with the second adult generation emerging in late August–September. The larvae feed on the needles of *Pinus densiflora* and *P. thunbergii*. In their native area, they can also feed on the North American species *P. strobus*, *P. taeda*, *P. rigida* and on the Chinese species *P. tabuliformis*. The young larvae feed on needles grown in the current year but older larvae prefer needles of the previous year (EPPO, 2004), and populations are more abundant in young plantations (Kamata, 2002).

Choi et al. (2011) studied *D. spectabilis* development at 17, 20, 25, 28 and 32°C and developed a phenology model. According to Choi et al. (2019), the lower development threshold is 3.2°C for the eggs and 0.9°C for the larvae. The minimum development temperature for 4th instar larvae is 7.6°C and the optimal temperature is 29.8°C; for pupae, the minimum development temperature is 12.5°C and the optimal temperature is 30.4°C.

Kong et al. (2001, 2003) identified the sex pheromone of *D. spectabilis* as (*Z*,*E*)-5,7-dodecadien-1-ol (*Z*5,*E*7-12: OH); in addition, *Z*5,*E*7-12:OAc and *Z*5,*E*7-12:OPr are minor components which increase the pheromone's attractiveness in field tests.

Natural enemies are described as significant factors of population density changes in Japan (Kokubo, 1965) and the Republic of Korea (Choi et al., 2019). Three hymenopteran egg parasitoids, *Trichogramma dendrolimi* Mastumura (Trichogrammatidae), *Telenomus dendrolimi* (Mastumura) (Scelionidae) and *Anastatus japonicus* Ashmead (Eupelmidae) have been described in Japan (Hirose et al., 1968a,b), as well as two larval parasitoids, the tachinid fly, *Carcelia bombylans* Robineau-Desvoidy (Kokubo, 1964), and the ichneumonid wasp, *Therion giganteum* (Gravenhorst) (Shimizu et al., 2018). All these parasitoids are present in Europe, except *Telenomus dendrolimi*, which is restricted to China, Japan and the republic of Korea (CABI, online). Ants have also been reported as effective natural enemies (Kim and Murakami, 1980). The fungus *Beauveria bassiana* has experimentally been shown to allow some control of *D. spectabilis*. A cytoplasmic polyhedrosis virus applied over 395 ha, led to a 34–90% population reduction (Kunimi, 2007).

In addition to voltinism and natural enemies, population changes seem influenced by climatic factors. In China, Bao et al. (2019) report a positive influence of drought on outbreaks.

3.1.3. Host range/Species affected

The larvae of *D. spectabilis* feed on the needles of *Pinus densiflora* and *P. thunbergii*. They can also feed on *P. strobus*, *P. taeda*, *P. rigida* and *P. tabuliformis* (Satomi et al., 1997; EPPO, 2004; Choi et al., 2019). *Abies* spp., *Cedrus* spp. and *Larix* spp. are also reported as hosts (EPPO, online). In Japan, *Cedrus deodara*, *Abies firma* and *Tsuga sieboldii* have been identified as host plants (Prof. Naoto Kamata, University of Tokyo, pers. comm.) The full list of host plants is presented in Appendix A.

3.1.4. Intraspecific diversity

No intraspecific diversity has been reported for this species.

3.1.5. Detection and identification of the pest

Are detection and identification methods available for the pest?
Yes, the pest has been clearly described and, in addition to morphological identification, can be identified using molecular markers. Sampling procedures also exist, a pheromone has been identified and an efficient lure has been experimentally tested albeit it does not seem to be commercially available.

Detection

Visual methods allow eggs and larvae to be detected, especially at high population densities (Kokubo, 1965). Furuta (1985) used 40x15 cm quadrats to count egg masses and larvae in the foliage. Quantitative assessments are also possible by measuring the amount of caterpillar frass falling to the ground (Kobayashi and Yamazaki, 1976).

The sex pheromone of *D. spectabilis* and some minor components, have been identified (Kong et al., 2001, 2003). There is no indication in the literature, however, that a commercial lure has been produced.

Identification

Morphological traits allow identification (Yamamoto, 1981; Choi et al., 2019). These latter authors provide the following description: 'The body length of PC adults is about 30 mm for males and 40 mm for females, with a wingspan ranging from 50 to 67 mm in males and 64–88 mm in females (. . .). Eggs are reddish brown and blue-brown ovals, and their diameter is about 2 mm; larvae are dark yellow-grey with an irregular pattern of dark orange and light grey'. *D. spectabilis* can also be distinguished from *D. okinawanus* and *D. punctatus punctatus* by their female genitalia (Yamamoto, 1981).

Molecular markers have also been identified. The complete mitochondrial genome has been sequenced (Kim et al., 2016), and a mitochondrial phylogeny of six *Dendrolimus* species including *D. spectabilis* has been proposed by Qin et al. (2019). These latter authors found that, with a success rate of 94.10–97.40%, a COI barcode outperformed two nuclear internal transcribed spacer (ITS) genes, which obtained a success rate of 64.70–81.60%. Ten pairs of informative primers allowing AFLP fingerprinting have also been described by Wang et al. (2009). Sequences are deposited at GenBank – NCBI (https://www.ncbi.nlm.nih.gov/search/all/?term=dendrolimus%20spectabilis).

3.2. Pest distribution

3.2.1. Pest distribution outside the EU

D. spectabilis occurs in Russia (Eastern Siberia, Russian Far East), China (Hebei, Heilongjiang, Jiangsu, Jilin, Liaoning, Shandong), Japan (Hokkaido, Honshu, Kyushu, the Ryukyu Archipelago), in the Republic of Korea, the Democratic People's Republic of Korea and Taiwan. Figure 1 shows the global distribution of *D. spectabilis*. Appendix B provides details of the global distribution based on the EPPO Global Database (EPPO, online).

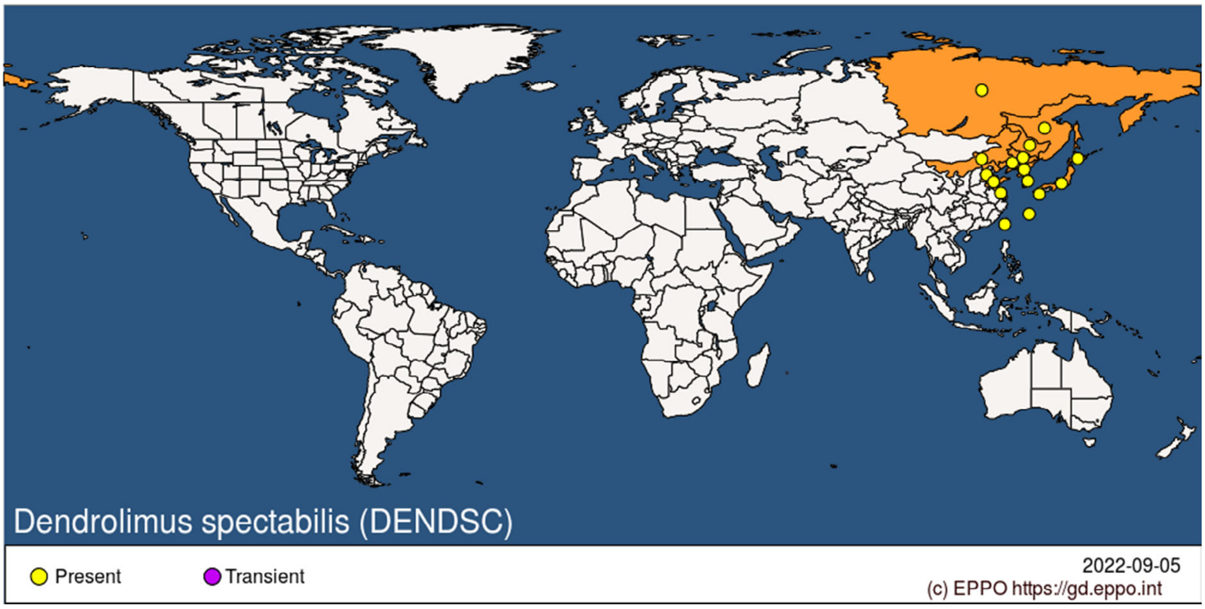

Figure 1: Global distribution of *Dendrolimus spectabilis* (Source: EPPO Global Database accessed on 5 September 2022)

3.2.2. Pest distribution in the EU

Is the pest present in the EU territory? If present, is the pest in a limited part of the EU or is it scarce, irregular, isolated or present infrequently? If so, the pest is considered to be not widely distributed.

No. *D. spectabilis* is not known to be present in the EU territory.

3.3. Regulatory status

3.3.1. Commission Implementing Regulation 2019/2072

D. spectabilis is included in a list of pests of concern in relation to naturally or artificially dwarfed *Pinus parviflora* and *P. thunbergii* plants for planting from Japan in Commission Implementing Regulation (EU) 2020/1217. The regulation provides for a derogation from Article 7, point 1 of Annex VI of Implementing Regulation (EU) 2019/2072 if the plants comply with the conditions set out in Commission Implementing Regulation (EU) 2020/1217.

3.3.2. Hosts or species affected that are prohibited from entering the union from third countries

Table 2: List of plants, plant products and other objects that are *Dendrolimus spectabilis* hosts whose introduction into the Union from certain third countries is prohibited (Source: Commission Implementing Regulation (EU) 2019/2072, Annex VI)

List of plants, plant products and other objects whose introduction into the Union from certain third countries is prohibited			
	Description	**CN Code**	**Third country, group of third countries or specific area of third country**
1.	Plants of *Abies* Mill., *Cedrus* Trew, *Chamaecyparis* Spach, *Juniperus* L., *Larix* Mill., *Picea* A. Dietr., *Pinus* L., *Pseudotsuga* Carr. and *Tsuga* Carr., other than fruit and seeds	ex 0602 20 20 ex 0602 20 80 ex 0602 90 41 ex 0602 90 45 ex 0602 90 46 ex 0602 90 47 ex 0602 90 50 ex 0602 90 70 ex 0602 90 99 ex 0604 20 20 ex 0604 20 40	Third countries other than: Albania, Andorra, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Canary Islands, Faeroe Islands, Georgia, Iceland, Liechtenstein, Moldova, Monaco, Montenegro, North Macedonia, Norway, Russia (only the following parts: Central Federal District (Tsentralny federalny okrug), Northwestern Federal District (Severo-Zapadny federalny okrug), Southern Federal District (Yuzhny federalny okrug), North Caucasian Federal District (Severo-Kavkazsky federalny okrug) and Volga Federal District (Privolzhsky federalny okrug)), San Marino, Serbia, Switzerland, Turkey, Ukraine and the United Kingdom.
19.	Soil as such consisting in part of solid organic substances	ex 2,530 90 00 ex 3,824 99 93	Third countries other than Switzerland

(Note the derogation referred to above under Section 3.3.1).

3.4. Entry, establishment and spread in the EU

3.4.1. Entry

Is the pest able to enter into the EU territory? If yes, identify and list the pathways.

Yes, the pest is able to enter the EU, either as eggs, larvae or pupae in the foliage of plants for planting or cut branches, as larvae on wood with bark, or as overwintering larvae in the litter of potted plants.

Comment on plants for planting as a pathway.

Plants for planting could, in principle, provide a pathway but the pathway is closed due to prohibition, with the exception of artificially dwarfed *P. thunbergii* from Japan (EU 2020/2017).

Annex VI of 2019/2072 prohibits the introduction of *D. spectabilis* hosts (*Pinus* spp.) from countries and areas where *D. spectabilis* occurs (Table 3). Certain dwarfed *Pinus* spp. from Japan are provided a derogation by EU 2020/1217.

Table 3: Potential pathways for *Dendrolimus spectabilis* into the EU 27

Pathways	Life stage	Relevant mitigations [e.g. prohibitions (Annex VI), special requirements (Annex VII) or phytosanitary certificates (Annex XI) within Implementing Regulation 2019/2072]
Plants for planting of *Pinus* spp. *Abies* spp., *Cedrus* spp., *Tsuga* spp. and *Larix* spp.	Eggs and larvae on needles and branches, larvae and pupae on bark and branches, larvae in the litter of potted plants	2019/2072 Annex VI prohibition
Cut branches of *Pinus* spp., *Abies* spp., *Cedrus* spp., *Tsuga* spp. and *Larix* spp. (including Christmas trees)	Eggs and larvae on needles and branches, larvae and pupae on bark and branches	2019/2072 Annex VI prohibition
Wood with bark of host plants	Larvae on bark	2019/2072 Annex VI prohibition
Isolated bark of host plants	Larvae on bark	2019/2072 Annex VI prohibition
Soil	Overwintering larvae	2019/2072 Annex VI prohibition

Notifications of interceptions of harmful organisms began to be compiled in Europhyt in May 1994 and in TRACES in May 2020. As of 29 July 2022, the only record of *D. spectabilis* interception occurred on dwarf *P. thunbergii* imported from Japan in April 2018 prior to the prohibition (annex VI of 2019/2072).

The EFSA Panel on Plant Health (2019) commodity risk assessment of black pine (*P. thunbergii*) bonsai from Japan (EFSA PLH Panel, 2019) rated pest freedom of these commodities from *D. spectabilis* as 'extremely likely' (median: 99.3%; 5% quantile: 99.9%; 95% quantile: 99.97%).

The EFSA Panel on Plant Health (2022) commodity risk assessment of bonsai plants from China consisting of *P. parviflora* grafted on *P. thunbergii* estimated pest freedom from *D. spectabilis* for bonsai plants following evaluation of proposed risk mitigation measures as 'almost always pest free' with the 90% uncertainty range spanning from 'pest free with some exceptional cases' to 'almost always pest free'. An Expert Knowledge Elicitation indicated, with 95% certainty, that between 9,983 and 10,000 plants per 10,000 would be free from *D. spectabilis*.

3.4.2. Establishment

Is the pest able to become established in the EU territory?

Yes, the pest is able to become established in the EU territory. There are ornamental hosts occurring in the EU and potential host plants in forestry, e.g. *Pinus* spp., are widespread. The EU climate matches with several areas found in its area of origin.

Climatic mapping is the principal method for identifying areas that could provide suitable conditions for the establishment of a pest taking key abiotic factors into account (Baker, 2002). Availability of hosts is considered in Section 3.4.2.1. Climatic factors are considered in Section 3.4.2.2.

3.4.2.1. EU distribution of main host plants

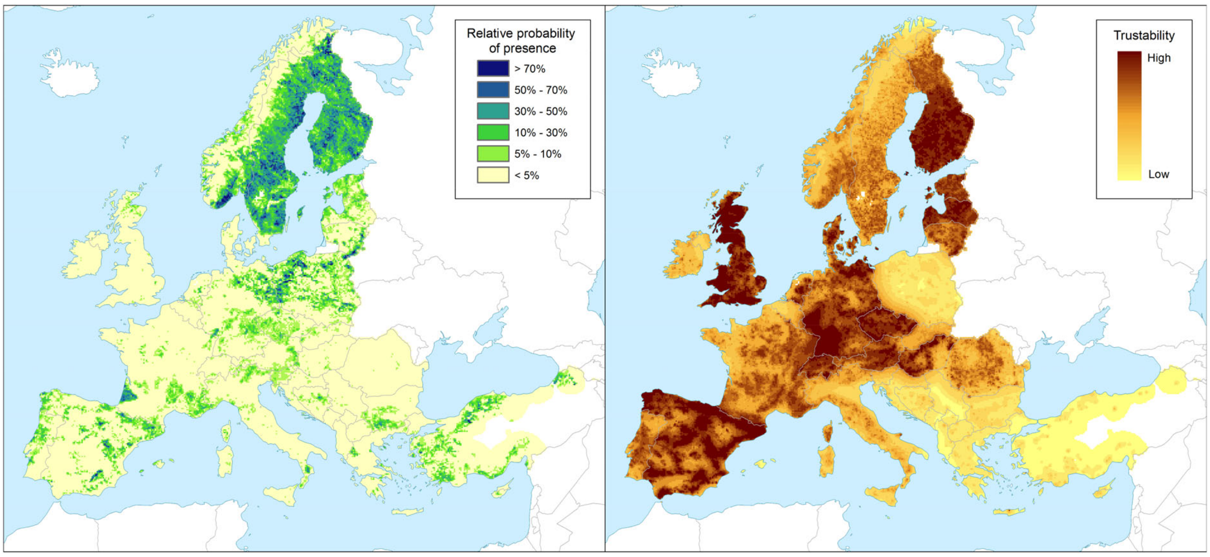

Figure 2: Left panel: Relative probability of the presence (RPP) of the genus *Pinus* in Europe, mapped at 100 km^2 resolution. The underlying data are from European-wide forest monitoring data sets and from national forestry inventories based on standard observation plots measuring in the order of hundreds m^2. RPP represents the probability of finding at least one individual of the taxon in a standard plot placed randomly within the grid cell. For details, see Appendix C (courtesy of JRC, 2017). Right panel: Trustability of RPP. This metric expresses the strength of the underlying information in each grid cell and varies according to the spatial variability in forestry inventories. The colour scale of the trustability map is obtained by plotting the cumulative probabilities (0–1) of the underlying index (for details, see Appendix C)

The most common native hosts in the pest's native range, *P. densiflora* and *P. thunbergii*, are two-needle pines. However, in its native area, *D. spectabilis* can develop on the North American pines *P. strobus* and *P. taeda* (see Sections 3.1.2 and 3.1.3). These three latter species are respectively a five-needle and two three-needle species, and they belong to different subgroups within the *Pinus* genus. This suggests some host plasticity in this pest and a capacity to shift to local conifer species in the EU territory, e.g. *P. sylvestris*, *P. nigra*, *P. maritima*.

3.4.2.2. Climatic conditions affecting establishment

The global Köppen–Geiger climate zones (Kottek et al., 2006) describe terrestrial climate in terms of average minimum winter temperatures and summer maxima, amount of precipitation and seasonality (rainfall pattern). Some climatic zones in which *D. spectabilis* occurs (Dfb, Dfc, Cfa, Cfb and, marginally, BSk) are also found in the EU (Figure 3).

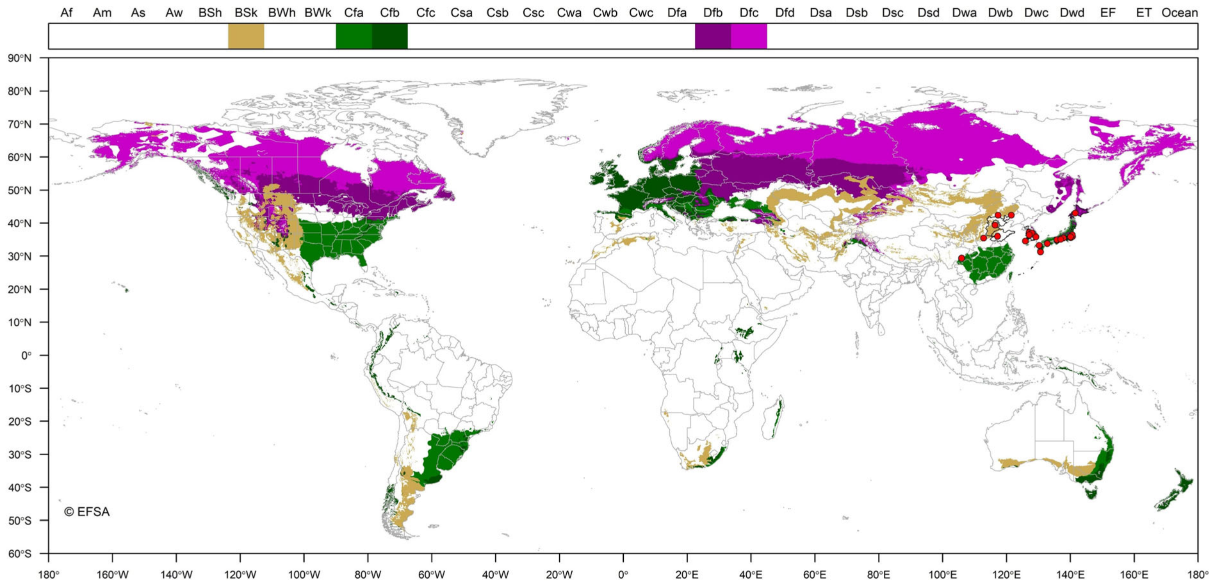

Figure 3: World distribution of Köppen–Geiger climate types that occur in the EU and which occur in sites where *Dendrolimus spectabilis* has been reported

For other species with similar biology (*D. sibiricus* and *D. superans*), the issue of the larvae requiring snow cover to successfully overwinter in the soil was raised (VKM, 2018; EFSA, 2018b). There are areas in the EU with permanent snow cover during the winter, which could allow successful overwintering of the fifth instar larvae. However, *D. spectabilis* is also established in several warm locations, e.g. Southern Japan, where there are mild winter conditions without snow cover, suggesting that establishment is possible in the EU in areas with no snow cover during the winter.

3.4.3. Spread

Describe how the pest would be able to spread within the EU territory following establishment?

The pest would be able to spread either with plants for planting or by adult flight.

Comment on plants for planting as a mechanism of spread.

Eggs, larvae or pupae could be transported with the needles of potted conifers, and overwintering larvae could travel in the litter of potted plants.

Flight

The literature provides no information regarding the flight capacity of the species. However, considering that its size is similar to that of *D. sibiricus* (female wingspan: 64–88 mm), and that *D. sibiricus* adults showed dispersal capacities of 15 to 50 km (EFSA, 2018b and references therein), *D. spectabilis* is likely to be able to disperse widely by flight.

If infested potted *Pinus* plants circulate within the EU, the pest's spread could be considerable.

3.5. Impacts

Would the pests' introduction have an economic or environmental impact on the EU territory?

Yes, the pest would have an economic and environmental impact on the EU territory.

Satomi et al. (1997), studying an outbreak of *D. spectabilis* on 68-year-old *P. strobus* (a North American species) in Hokkaido, that resulted in severe defoliation, recorded a clear adverse effect of defoliation on annual increment for 5 years after the outbreak. More generally defoliation can lead to increased vulnerability to other agents such as bark beetles, to top kills and to higher mortality, e.g. as observed by Langström et al. (2001) on *P. sylvestris* defoliated by the sawfly *Diprion pini* and colonised afterward by *Tomicus piniperda*. In addition to economic damage, tree mortality increases the risk of forest fires and could also alter stand composition and, hence, cause environmental impacts across the landscape as a whole. In China (Shandong Province), Bao et al. (2019) established a positive link between drought and *D. spectabilis* outbreaks. Under climate change, in a drier future, increased damage might be expected.

There is also considerable uncertainty over the impact of the pest in conifer species in EU.

3.6. Available measures and their limitations

Are there measures available to prevent pest entry, establishment, spread or impacts such that the risk becomes mitigated?

Yes, Annex VI of 2019/2072 prohibits the introduction of plants and plant products of *Pinus* spp., *Abies* spp., *Cedrus* spp. and *Larix* spp. from many third countries, including countries and areas where *D. spectabilis* occurs.

Annex VI of 2019/2072 prohibits the introduction of plants and plant products of *Pinus* spp., *Abies* spp., *Cedrus* spp., *Tsuga* spp. and *Larix* spp. from many third countries, including countries and areas where *D. spectabilis* occurs. EPPO (2018) suggests commodity specific phytosanitary measures for Coniferae.

Natural enemies are described as significant factors of population density changes in Japan (see Section 3.1.2 Biology of the pest). Hymenopteran egg parasitoids, *Trichogramma dendrolimi*, *Telenomus dendrolimi* and *Anastatus japonicus* have been described in Japan (Hirose et al., 1968a,b), as well as two larval parasitoids, *Carcelia bombylans* (Kokubo, 1964) and *Therion giganteum* (Shimizu et al., 2018).

The entomopathogenic fungus *Beauveria bassiana* has experimentally been shown to allow some control of *D. spectabilis* and, over a 395 ha experiment, the release of a cytoplasmic polyhedrosis virus led to a 34–90% population reduction (Kunimi, 2007).

3.6.1. Identification of potential additional measures

Phytosanitary measures (prohibitions) are applied to the host genus (see Section 3.3.2). If these prohibitions stay in place, additional measures will not increase protection. Therefore, no additional measures have been identified.

A derogation for dwarfed *P. thunbergii* from Japan details the necessary requirements for the introduction of the plants into the EU (EU 2020/1217) and we do not suggest further measures are necessary.

3.6.1.1. Additional potential risk reduction options

Given the existing prohibition no additional risk reduction options are warranted. In the specific case of the derogation regarding bonsai from Japan, the derogation specifies the necessary risk mitigation measures.

3.6.1.2. Additional supporting measures

Given the existing prohibition and requirements for the derogation from Japan no additional supporting measures have been identified.

3.7. Uncertainty

There is lack of information regarding whether *D. spectabilis* could feed and develop on conifer species commonly occurring in the EU.

4. Conclusions

D. spectabilis satisfies the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest (Table 4).

Table 4: The Panel's conclusions on the pest categorisation criteria defined in Regulation (EU) 2016/2031 on protective measures against pests of plants (the number of the relevant sections of the pest categorisation is shown in brackets in the first column)

Criterion of pest categorisation	Panel's conclusions against criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest	Key uncertainties
Identity of the pest (Section 3.1)	The identity of the species is established and *Dendrolimus spectabilis* (Butler) is the accepted scientific name and authority.	None
Absence/presence of the pest in the EU (Section 3.2)	*D. spectabilis* is not known to be present in the EU territory	None
Pest potential for entry, establishment and spread in the EU (Section 3.4)	*D. spectabilis* could enter the EU on host plants for planting and plant products such as cut branches or wood with bark. However, Annex VI of 2019/2072 prohibits the introduction of *D. spectabilis* hosts (*Pinus, Abies, Larix, Tsuga* and *Cedrus*) from countries and areas where *D. spectabilis* occurs. There is a derogation for artificially dwarfed *P. thunbergii* plants from Japan and there have been interceptions on imports. Whilst there are climate zones in the EU that match those found where	There is a lack of information regarding whether *D. spectabilis* could feed and develop on conifer species commonly occurring in the EU for forestry, although ornamental hosts do occur in the EU. This uncertainty affects impact.
Potential for consequences in the EU (Section 3.5)	*D. spectabilis* is described as a pest of conifer forests in northeast China, Japan and the Republic of Korea. However, reports of damage are to *Pinus* species not occurring in EU. The magnitude of economic and environmental impacts in the EU would depend on whether *D. spectabilis* could feed and develop on EU conifer species. Impacts could nevertheless still occur in ornamental hosts.	There is a lack of information regarding whether *D. spectabilis* could feed and develop on conifer species occurring in the EU.
Available measures (Section 3.6)	Annex VI of 2019/2072 prohibits the introduction of plants and plant products of *D. spectabilis* host genera from many third countries, including countries and areas where *D. spectabilis* occurs. Furthermore, in the specific case of derogation regarding bonsai from Japan, risk mitigation options are listed.	None
Conclusion (Section 4)	*D. spectabilis* satisfies all the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest. Whether European forestry conifers could act as hosts is unknown but is fundamental, affecting the extent of establishment and the magnitude of impact.	There is a lack of information regarding whether t *D. spectabilis* could feed and develop on conifer species commonly occurring in the EU.
Aspects of assessment to focus on/scenarios to address in future if appropriate	It would be useful to find out whether *D. spectabilis* could feed and reproduce on conifer species commonly used in EU forestry. Such information would reduce the key uncertainty within this pest categorisation.	

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Abbreviations

EPPO	European and Mediterranean Plant Protection Organisation
FAO	Food and Agriculture Organisation
IPPC	International Plant Protection Convention
ISPM	International Standards for Phytosanitary Measures
MS	Member State
PLH	EFSA Panel on Plant Health
PZ	Protected Zone
TFEU	Treaty on the Functioning of the European Union
ToR	Terms of Reference

Glossary

Containment (of a pest)	Application of phytosanitary measures in and around an infested area to prevent spread of a pest (FAO, 2018)
Control (of a pest)	Suppression, containment or eradication of a pest population (FAO, 2018)
Entry (of a pest)	Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO, 2018)
Eradication (of a pest)	Application of phytosanitary measures to eliminate a pest from an area (FAO, 2018)
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO, 2018)
Greenhouse	A walk-in, static, closed place of crop production with a usually translucent outer shell, which allows controlled exchange of material and energy with the surroundings and prevents release of plant protection products (PPPs) into the environment
Hitchhiker	An organism sheltering or transported accidentally via inanimate pathways including with machinery, shipping containers and vehicles; such organisms are also known as contaminating pests or stowaways (Toy and Newfield, 2010)

Impact (of a pest)	The impact of the pest on the crop output and quality and on the environment in the occupied spatial units
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO, 2018)
Pathway	Any means that allows the entry or spread of a pest (FAO, 2018)
Phytosanitary measures	Any legislation, regulation or official procedure having the purpose to prevent the introduction or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (FAO, 2018)
Quarantine pest	A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO, 2018)
Risk reduction option (RRO)	A measure acting on pest introduction and/or pest spread and/or the magnitude of the biological impact of the pest should the pest be present. A RRO may become a phytosanitary measure, action or procedure according to the decision of the risk manager
Spread (of a pest)	Expansion of the geographical distribution of a pest within an area (FAO, 2018)

Appendix A – *Dendrolimus spectabilis* host plants/species affected

Host status	Host name	Plant family	Common name	Reference
Cultivated hosts	*Abies*	Pinaceae	Firs	EPPO (online)
	Cedrus	Pinaceae	Cedars	EPPO (online)
	Larix	Pinaceae	Larches	EPPO (online)
	Pinus	Pinaceae	Pines	EPPO (online)
	Cedrus deodara *Abies firma* *Tsuga sieboldii*	Pinaceae Pinaceae Pinaceae	Himalayan cedar Momy fir; Japanese fir southern Japanese hemlock	N. Kamata, pers. comm.
	*Pinus densiflora**	Pinaceae	Japanese umbrella pine	EPPO (online)
	*Pinus thunbergii**	Pinaceae	Japanese black pine	EPPO (online)
	*Pinus strobus**	Pinaceae	White pine	EPPO (2004); Satomi et al. (1997)
	*Pinus taeda**	Pinaceae	Loblolly pine	EPPO (2004)
	*Pinus rigida**	Pinaceae	Pitch pine	Choi et al. (2011)
	*Pinus tabuliformis**	Pinaceae	Manchurian red pine	EPPO (2004)

Source: EPPO Global Database (EPPO, online); EPPO, 2004; Satomi et al., 1997; Choi et al., 2011.
*: grown in EU as an ornamental.

Appendix B – Distribution of *Dendrolimus spectabilis*

Distribution records based on EPPO Global Database (EPPO, online)

Region	Country	Sub-national (e.g. State)	Status
Other Europe	Russia		Present, no details
		Eastern Siberia	Present, no details
		Far East	Present, no details
Asia	China		Present, no details
		Hebei	Present, no details
		Heilongjiang	Present, no details
		Jiangsu	Present, no details
		Jilin	Present, no details
		Liaoning	Present, no details
		Shandong	Present, no details
	Japan		Present, no details
		Hokkaido	Present, no details
		Honshu	Present, no details
		Kyushu	Present, no details
		Shikoku	Present, no details
		Ryukyu Archipelago	Present, no details
	Korea Dem. People's Republic		Present, no details
	Korea, Republic		Present, no details
	Taiwan		Present, no details

Japan (Shikoku): http://www.jpmoth.org/~dmoth/70_Lasiocampidae/2975Dendrolimus_spectabilis/Dendrolimus_spectabilis.htm

Appendix C – Methodological notes on Figure 2

The relative probability of presence (RPP) reported here and in the European Atlas of Forest Tree Species (de Rigo et al., 2016; San-Miguel-Ayanz et al., 2016) is the probability of a species, and sometimes a genus, occurring in a given spatial unit (de Rigo et al., 2017). The maps of RPP are produced by spatial multi-scale frequency analysis (C-SMFA) (de Rigo et al., 2014, 2016) of species presence data reported in geolocated plots by different forest inventories.

Geolocated plot databases

The RPP models rely on five geo-databases that provide presence/absence data for tree species and genera (de Rigo et al., 2014, 2016, 2017). The databases report observations made inside geo-localised sample plots positioned in a forested area, but do not provide information about the plot size or consistent quantitative information about the recorded species beyond presence/absence.

The harmonisation of these data sets was performed as activity within the research project at the origin of the European Atlas of Forest Tree Species (de Rigo et al., 2016; San-Miguel-Ayanz, 2016; San-Miguel-Ayanz et al., 2016). All data sets were harmonised to an INSPIRE compliant geospatial grid, with a spatial resolution of 1 km^2 pixel size, using the ETRS89 Lambert Azimuthal Equal-Area as geospatial projection (EPSG: 3035, http://spatialreference.org/ref/epsg/etrs89-etrs-laea/).

European National Forestry Inventories database This data set derived from National Forest Inventory data and provides information on the presence/absence of forest tree species in approximately 375,000 sample points with a spatial resolution of 1 km^2/pixel, covering 21 European countries (de Rigo et al., 2014, 2016).

Forest Focus/Monitoring data set This project is a Community scheme for harmonised long-term monitoring of air pollution effects in European forest ecosystems, normed by EC Regulation No. 2152/2003[2]. Under this scheme, the monitoring is carried out by participating countries on the basis of a systematic network of observation points (Level I) and a network of observation plots for intensive and continuous monitoring (Level II). For managing the data, the JRC implemented a Forest Focus Monitoring Database System, from which the data used in this project were taken (Hiederer et al., 2007; Houston Durrant and Hiederer, 2009). The complete Forest Focus data set covers 30 European Countries with more than 8,600 sample points.

BioSoil data set This data set was produced by one of a number of demonstration studies initiated in response to the 'Forest Focus' Regulation (EC) No. 2152/2003 mentioned above. The aim of the BioSoil project was to provide harmonised soil and forest biodiversity data. It comprised two modules: a Soil Module (Hiederer et al., 2011) and a Biodiversity Module (Houston Durrant et al., 2011). The data set used in the C-SMFA RPP model came from the Biodiversity module, in which plant species from both the tree layer and the ground vegetation layer was recorded for more than 3,300 sample points in 19 European Countries.

European Information System on Forest Genetic Resources (EUFGIS) is a smaller geo-database that provides information on tree species composition in over 3,200 forest plots in 34 European countries. The plots are part of a network of forest stands managed for the genetic conservation of one or more target tree species. Hence, the plots represent the natural environment to which the target tree species are adapted EEUFGIS, online.

Georeferenced Data on Genetic Diversity (GD^2) is a smaller geo-database as well. It provides information about a 63 species that are of interest for genetic conservation. It counts 6,254 forest plots that are located in stands of natural populations that are traditionally analysed in genetic surveys. While this database covers fewer species than the others, it does covers 66 countries in Europe, North Africa, and the Middle East, making it the data set with the largest geographic extent (INRA, online).

Modelling methodology

For modelling, the data were harmonised in order to have the same spatial resolution (1 km^2) and filtered to a study area that comprises 36 countries in the European continent. The density of field observations varies greatly throughout the study area and large areas are poorly covered by the plot databases. A low density of field plots is particularly problematic in heterogenous landscapes, such as

[2] Regulation (EC) No 2152/2003 of the European Parliament and of the Council of 17 November 2003 concerning monitoring of forests and environmental interactions in the Community (Forest Focus). Official Journal of the European Union 46 (L 324), 1–8.

mountainous regions and areas with many different land use and cover types, where a plot in one location is not representative of many nearby locations (de Rigo et al., 2014). To account for the spatial variation in plot density, the model used here (C-SMFA) considers multiple spatial scales when estimating RPP.

C-SMFA preforms spatial frequency analysis of the geolocated plot data to create preliminary RPP maps (de Rigo et al., 2014). For each 1-km^2 grid cell, it estimates kernel densities over a range of kernel sizes to estimate the probability that a given species is present in that cell. The entire array of multi-scale spatial kernels is aggregated with adaptive weights based on the local pattern of data density. Thus, in areas where plot data are scarce or inconsistent, the method tends to put weight on larger kernels. Wherever denser local data are available, they are privileged ensuring a more detailed local RPP estimation. Therefore, a smooth multi-scale aggregation of the entire arrays of kernels and data sets is applied instead of selecting a local 'best preforming' one and discarding the remaining information. This array-based processing, and the entire data harmonisation procedure, are made possible thanks to the semantic modularisation which define Semantic Array Programming modelling paradigm (de Rigo, 2012).

The probability to find a single species in a 1-km^2 grid cell cannot be higher than the probability of presence of all the broadleaved (or coniferous) species combined, because all sample plots are localised inside forested areas. Thus, to improve the accuracy of the maps, the preliminary RPP values were constrained to not exceed the local forest-type cover fraction (de Rigo et al., 2014). The latter was estimated from the 'Broadleaved forest', 'Coniferous forest' and 'Mixed forest' classes of the Corine Land Cover (CLC) maps (Bossard et al., 2000; Büttner et al., 2012), with 'Mixed forest' cover assumed to be equally split between broadleaved and coniferous.

The robustness of RPP maps depends strongly on sample plot density, as areas with few field observations are mapped with greater uncertainty. This uncertainty is shown qualitatively in maps of 'RPP trustability'. RPP trustability is computed on the basis of aggregated equivalent number of sample plots in each grid cell (equivalent local density of plot data). The trustability map scale is relative, ranging from 0 to 1, as it is based on the quantiles of the local plot density map obtained using all field observations for the species. Thus, trustability maps may vary among species based on the number of databases that report it (de Rigo et al., 2014, 2016).

The RPP and relative trustability range from 0 to 1 and are mapped at 1 km spatial. To improve visualisation, these maps can be aggregated to coarser scales (i.e. 10 $\times$ 10 pixels or 25 $\times$ 25 pixels, respectively summarising the information for aggregated spatial cells of 100 and 625 km^2) by averaging the values in larger grid cells.